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A New Approach for Retrieving Surface Soil Moisture and Vegetation Parameters

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Abstract

A new approach for retrieving surface soil moisture and vegetation parameters based on multi-angular L-band brightness temperature data is presented in this paper. Relationships of soil emissivity at different incidence angles are derived using Advanced Integral Equation Model simulated database, and a linear function for brightness temperatures with two incidence angles is derived, in which the intercept and slope depend only on vegetation properties. Soil moisture can be retrieved using dual-polarization observations after surface roughness corrections based on a parameterized surface emission model. Validation using soil moisture networks indicates that this approach performs well in surface soil moisture retrieval. Retrieved soil moisture agrees well with *in situ* measurements with the rmse close to 0.04 m^3/m^3 .

Keywords

Microwave Remote Sensing; SMOS; Soil Moisture; Multi-Angular

Introduction

Soil Moisture is a key variable in the land-atmosphere interactions and climate system, and it plays an important role in global water cycle. Traditionally, soil moisture is measured from in situ sampling measurements which only represent a relatively small area around the location. However, surface soil moisture is difficult to estimate accurately at large spatial scale. With the launch of several space-borne microwave sensors, passive microwave remote sensing has been proven to be an effective technique to obtain global soil moisture. For vegetation-covered surfaces, measured microwave signals contain not only signals from the underlying soil but also that from the vegetation canopy. To retrieve accurate surface soil moisture, it is needed to decompose the observed signals into soil and vegetation components. The Soil Moisture and Ocean Salinity mission, which is the first L-band passive microwave space-borne sensor using synthetic aperture technique, was launched in November, 2009. It provides global L-band brightness temperature for a range of incidence angles at a spatial resolution of about 50km.

Multi-angular radiometer observations contain not only vegetation and soil signals but also the relationships of each parameter at different incidence angles. This paper presents a new approach to retrieve surface soil moisture and vegetation parameters based on multi-angular brightness temperature data. The uniqueness of this new approach is that it not only explores such angular relationships based on physical model simulations but also realizes simultaneous retrievals of soil moisture and vegetation parameters using multi-angular observations without the need of ancillary data.

Study Areas and Data

Little Washita Watershed study area is located in the southwest Oklahoma in the Great Plains region of the U.S. and covers about 610 km2 area. The climate is sub-humid with an average annual precipitation of 750 mm. The watershed's topography is moderately rolling except a few rocky steep hills in the northwest. Land cover is dominated by rangeland and pasture, but including winter wheat and cropland. Within this watershed, there is a total of 20 ARS Micronet stations which hasbeen used to validate AMSR-E and SMOS soil moisture products.

The SMOS Level 1c brightness temperature product is used in this study. the multi-angular observations are not obtained at fixed incidence angles, which is not suitable for our retrieval algorithm which requires observations at

specific incidence angles. To conquer these issues, a mixed objective function is used to fit forSMOS L1c brightness temperatures to expected incidence angles.

Retrieval Method

Multi-angular radiometer observations are used to solve simultaneously for soil moisture and vegetation parameters in our approach. Firstly, the relationship of soil emissivity at different incidence angles at H-polarization is characterized using AIEM simulated dataset. Based on this relationship, a linear function between brightness temperatures with two incidence angles at H-polarization can be derived. The intercept and slope of this linear function depend only on vegetation properties. Then, the vegetation optical depth τ_{NAD} and single scattering albedo ω are first estimated using observations of multiple pairs of incidence angles. Last, soil moisture can be retrieved using dual-polarization observations at incidence angle of 40^o after surface roughness correction based on a parameterized bare soil emission model.

The soil emissivity is affected by both soil moisture and roughness properties. In this study, the soil moisture is retrieved by Chen's bare soil emission model[22] which properly corrects the roughness effect and estimateestimates soil moisture directly. The model is based on a simple surface effective reflectivity expression:

$$R_p^e = A \cdot (\sigma_S / L_c)^B \cdot r_p^C \quad (1)$$

where R is the effective reflectivity, r is smooth surface reflectivity, σ_s and L_c are surface rms height and correlation length, respectively. The coefficients A, B and C are determined using simulated database from AIEM model and are dependent on polarization and incidence angle. The dependence on incidence angle of these coefficients for a given polarization can be described as:

$$A, B, C(\theta, p) = e + g \cdot \theta + h \cdot \theta^2 + k \cdot \theta^3 \quad (2)$$

The details of e, g, h and k can be found in Chen *et al.* validated their algorithm with field data sets and concluded that this algorithm performs well in soil moisture retrieval.

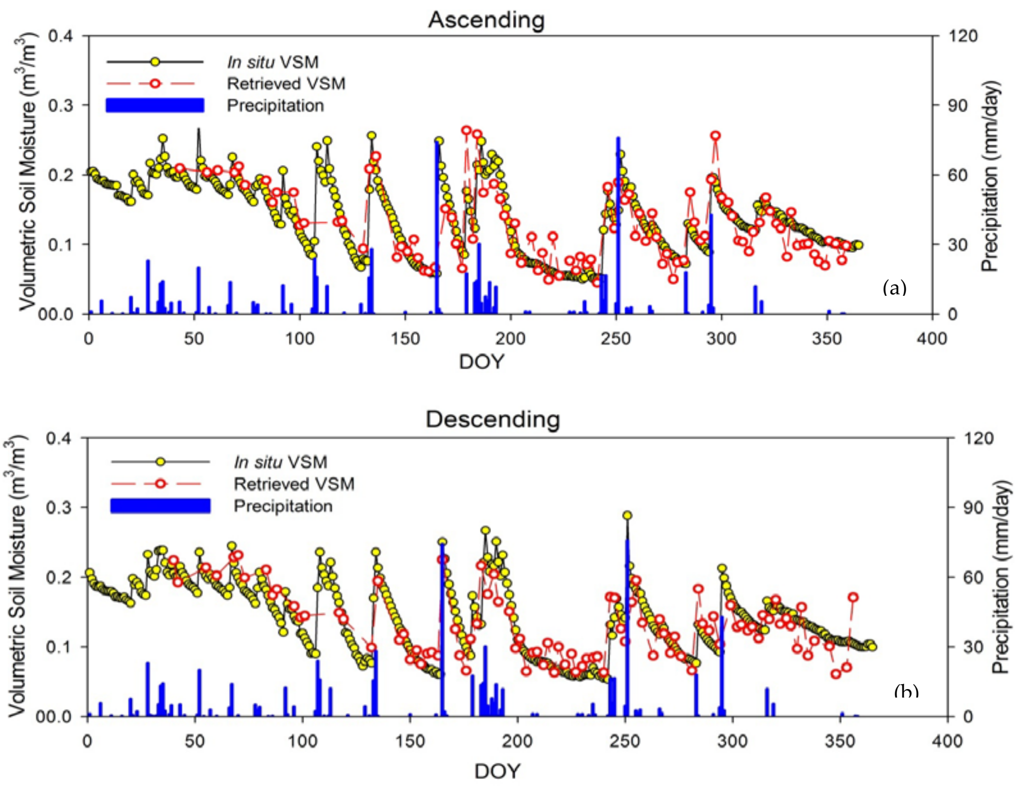

FIG. 1 TEMPORAL PLOTS OF IN SITU AND RETRIEVED SOIL MOISTURE BY THIS NEW APPROACH OVER LITTLE WASHITA FOR (A) ASCENDING AND (B) DESCENDING PASS IN 2010. DAILY PRECIPITATION DATA ARE ADDED FOR COMPARISON.

Results and Analysis

The average of the retrieved soil moisture within a study areas were compared to the in situ soil moisture derived by averaging all points in the study area at the time closest to overpassedtime.

Estimations of one-year soil moisture by this new approach along with the in situ soil moisture study areas are showed in FIG. 1. Daily precipitation data are also illustrated for comparison. It shows that the variation of retrievals correspond quite well with the *in situ* measurements in the study area. The rainfalls result in sudden increases in soil moisture and the retrieved soil moisture can generally reflect this dynamics. The retrievals indicate a good agreement with *in situ* soil moisture with the RMSE of 0.025 m^3/m^3 for ascending and 0.027 m^3/m^3 for descending in Little Washita. It is close to or better than the mission target accuracy of 0.04 m^3/m^3.

Conclusion

The new approach for retrieving surface soil moisture, vegetation single scattering albedo and optical depth using multi-angular brightness temperature data is presented in this paper. The vegetation optical depth τ_{NAD} and single scattering albedo ω can be first estimated through optimization method using multiple pairs of incidence angle observations. Soil moisture can be retrieved using dual-polarization observations at incidence angle based on bare soil emission model without roughness parameters. The Little Washita study area data was used to validate this approach. The results show the retrieved soil moisture using this new approach correspond well with the ground measurements of soil moisture with the rmse close to 0.025 m3/m3 for Little Washita. The annual variation agrees quite well with in situ soil moisture with high correlation coefficients. Compared to the precipitation data, it is also showed that this approach can capture the soil moisture dynamics resulted from rainfall on the wholearea.

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Liang Chen , worked on the validation of different passive and active microwave satellite products , with a particular focus on ESA's SMOS and NASA's SMAP. Since his graduation, he continues to work on land surface parameter retrieval. His current fields of interest are in the remote sensing of vegetation dynamics and landscape water content.